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DEVELOPMENT OF A LOW-PRESSURE FISH DRYER

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ABSTRACT:

Fish products are major sources protein supplements for human nourishment composing of low fat a whish cherished health wise by all consumers. Quite a substantial amount of this products harvest during are lost to spoilage due to untimely removal of moisture content an offshoot of inappropriate and inadequate processing methods, lack of advance short time drying outfits to assist the local processors to stall the fish spoilage mechanism orchestrated by activities of bacteria. To meet this short time to dry need and increase fish storage shelf life and overall productivity, an indigenous affordable vacuum dryer was conceived and developed locally. The unit was fabricated using locally sourced materials and was tested on catfish samples. A constant vacuum head of 3.6KPawas attained at pumping rate of 320l/hr, a temperature range of 38 and 42oC, energy and power level of 498.6KJ and 13.6W with an effective moisture diffusivity of 7.58× 10-11m2/s was recorded for the fish samples dried within 10 hours. Total moisture content removal efficiency of 85% was attained This method of drying was very effective in drying the fish samples and still requires further optimization studies to scale up the unit for commercial purpose.

***KEYWORDS:** Vacuum, Low Pressure, Fish, Dryer & Diffusivity*

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Original Article

1. INTRODUCTION

Fish consumption provides the highest source of protein with the lowest fat content food item for over 250 million people around the world. It consists of vital nutrients like; iodine, various vitamins, and minerals. The low fat content is advantageous to consumers in lowering the risk of heart attack and strokes most especially for old folks all around the world. Health wise, there are claims that its' consumption increases grey matter in the brain, thereby protecting it from aged related deterioration, reduces the risk of autoimmune diseases and others; diabetes, asthma in children, improves sleep quality for infant, aids vision at old age. However, fish supplies are falling to meet the demand in some critically poor countries these are major shortages that need urgent attention.

Additionally, fish yearly losses had been estimated to be 10 to 12 million tons per year globally (FAO (2010). This creates a high demand for fish products which in turn affects the cost and makes it unreachable to peasant consumers and children all over the world.

Fish, being an extremely perishable food (Clucas, 1975) that requires instant processing within twelve hours else spoilage set in. therefore begins as soon as the It is therefore essential to prevent or arrest the bacteria.

(Clucas,1975) that stimulates spoilage. Fish are known to consist80% moisture content and a reduction to around 25%, would prevent bacteria growth while a further drying to 15% or less would disallow mould formation (Clucas, 1982).

In order to do these various methods such as; salting, drying or tray batch smoke screens which may entail; application of hot air, indirect or contact drying, dielectric drying, freeze drying, supercritical drying other than natural air drying could be used by stakeholders in the fish business to preserve fish products.

The former methods had disadvantages which include exposure of the fish to rain and dust, uncontrolled drying, exposure to sunlight which are undesirable for such foodstuff. All this are the potential source of infestation and contamination of fish products that lead to food poisoning. To avoid all these problems and dangers that could arise in the continuous practice of all these old methods, a new different indigenous low-pressure dryer which is at variance to existing advance dryers used in developed countries reported in; (>>>>) was conceived, design and developed in this work.

2. CONCEPTUAL DESIGN OF THE LOW-PRESSURE DRYERDRYERDRYER

The conceived dryer shown in Figure 1 whose working principles was based on the creation of low vacuum head initiated by the high suction head of a wet vacuum motor. This motor was selected based on the size of dryer reported inAgu (2018). The motor operates at a very high speed in the average range of 24,000 rpm sucking out the air in the cabinet, containing the fish sample designed to be air intact while the air in it is extracted by vacuum. As the air was removed from the cabinet having the fish samples at the motor speed, low pressure is created in it and the water within the fish samples begin to boil under a temperature above the room temperature. To regularize this temperature the electrical system, a thermocouple was connected to a very low heater of 350 Watt. The whole operation of the vacuum pump was controlled by a thermocouple to pre-set temperature value of 38 to 42^{o}C.

Related literature found relevant with technical information utilized in this design work were; Faires and Simmang, 1978; David and Whitfield 2000; Earle,1983, Cengel and Boles, 2006; Joseph *et al* 1992; Holman 1997;Cengel and Boles, 2006; Baird Parker TC 2000; Getu, *et al* 2015 and Adebowale *et al* 2008.

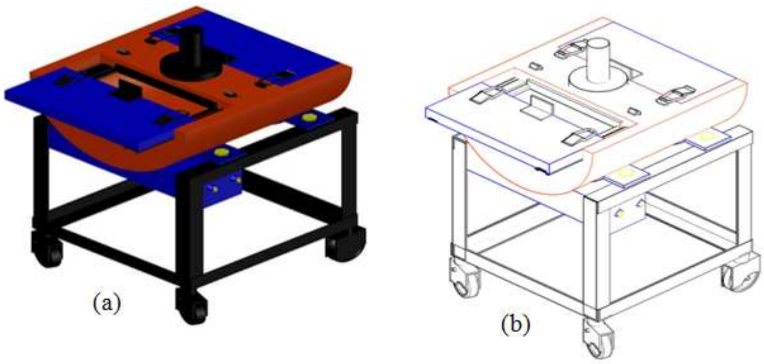

Figure 1: Low Pressure Fish Dryer (a) Rendered View (b) Isometric view

2.1 Theoretical Background

The following equations were used in the design of the low-pressure dryer;

- **The Rate of Water Removed from a Fish (Holman, 1997) is**

$$\frac{dm}{dt} = \frac{h_c A(T_a - T_w)}{h_{fg}} \tag{1}$$

Amount of water lost m_w= $\frac{hA(T_a - T_w)t}{h_{fg}}$ (2)

h_c =heat capacity($kjkg^{-1}k^{-1}$)

A=surface area(m^2)

T_a=air free stream temperature(^oc)

T_w=wet bulb temperature. (^oc)

h_{fg}=latent heat of vaporization.

h=heat of convection($kjkg^{-1}k^{-1}$)

t=time in secs.

- **The Energy Required during the Heat Transfer Process is**

Q=MC $\Delta\theta$ (3)

Q= Heat energy (joules)

M=Mass of the substance (kg)

C=specific heat capacity ($kjkg^{-1}k^{-1}$)

$\Delta\theta$ =k(kelvin)

- **Power Required for this Process** = $\frac{energy(KJ)}{time(Secs)}(\boldsymbol{Kw})$ (4)

- **The Moisture Content was Evaluated using Basic Models Reported in Joseph, *et al.*(1992).**

  - **Wet Basis**

Moisture content= $\left(\frac{M_w - M_d}{M_w}\right)\times 100$ (5)

M_w =mass of fish sample(kg).

M_d =mass of dried fish sample(kg).

$M_w - M_d$ =mass of water(kg).

- **Dry Basis**

$$\left(\frac{M_w - M_d}{M_d}\right) \times 100 \tag{6}$$

- **Moisture Diffusivity**: Diffusion represents the main mechanism during the transport of moisture to the surface to be evaporated. After plotting the graph of the "ln" function of moisture ratio against time and obtaining the slope. The slope of the plot can then be compared with $\left(\frac{\Pi^2 D_{eff}}{4L^2}\right)$ of which represent **m** in the equation of a straight line to obtain the effective moisture diffusivity.

$$\ln(MR) = \ln\left(\frac{8}{\Pi^2}\right) - \left(\frac{\Pi^2 D_{eff}}{4L^2}\right)t \tag{7}$$

(Sarimeseli,2011; Al-Harahsheh et al.,2009).

D_{eff} = effective moisture diffusivity(m^2/s),

L =half thickness of thin layer sample(m).

t= time

- **Time Taken to Degas from Initial Pressure(p_0) to Final Pressure (p_f)**

$$T = \frac{v}{s}\ln\frac{p_0}{p_f} \tag{8}$$

T=time taken to pump down from P_o to P_f (sec)

V=volume of the chamber(m^3)

S=suction capacity(m^3/sec)

P_0=atmospheric pressure(Pa)

P_f=final pressure(Pa)

- **Power Capacity of the Pump**

$$Q = SP \tag{9}$$

S=speed of the pump(rpm)

P=pressure(Pa)

- **Energy Required to Degass the Chamber**

$$E = P_O V \left[1 - e^{\frac{-st}{v}}\right] \ldots \tag{10}$$

E= Energy (joules)

P_O =initial pressure(Pa)

S=suction capacity(m^3/sec)

T=time (secs)

V=volume(m^3)

- **Thickness of the Shell**

$$\sigma_t = \frac{PD}{2t} \tag{11}$$

(khurmi*et al* 2005)

σ_t = stress in the material (N/m^2)

P = Pressure experienced in the shell (N/m^2)

D = Diameter of the shell. (m)

t= thickness of the shell. (m)

3. MATERIALS AND METHOD

The Engineering drawing of the dryer, specifications and component list are shown in Figure 2.and Table 1respectively. The design calculations were done using equations 1 to 9 to obtain the specification of parts and material selection given in Table 1. These parameters were factored into the design to ensure the utmost performance of the machine to meet up with an expected goal; timely drying of the fish samples. Sequel to the designing of the machine an oven drying method was used to dry samples of catfish to determine the exact water content of the samples. The knowledge of the average water content of fish samples was used in determining both the thermal energy required to dry a given set of fish samples. The number of fishes desired for this dryer was 10. The machine was fabricated and tested to determine its functionality and overall drying efficiency and quality of dried products. The machine consists of the following main parts; a heating element, a vacuum pump, thermocouple, and the drying chamber. The drying chamber was insulated; lagged with fiber glass to minimize the heat loss and stabilize the temperature of the chamber. The drying chamber cover was designed to ensure proper seal to prevent air leakage during operation to maintain the partial vacuum head required for drying within the system.

Table 1: List of Materials Used in Fabrication and their Specifications

S/N	Machine parts	Specifications	Quantity	Material type
1	Drying Chamber	Diameter 36 cm ×length 50 cm (1mm thickness)	1	Stainless steel
2	,Wheel		4	Rubber and steel
3	Vacuum Pump	1100 watts, suction 350l/hr	1	-
4	Control Box	1.2m by 1.2m	1	-
5	Seal	2inches by 2icnhes 18fts (5mm thickness)	1	Isobutylene-isoprene
6	Frame		1	Mild steel
7	Cover		2	Stainless steel
8	Support		1	Mild steel
9	Heating Element	350 Watts	1	-
10	Tray		1	Stainless steel

The dryer was used to dry two cat fish samples. The samples were prepared with the gut removed. The physical properties of the samples were determined before and after drying. These dimensional details of the fish samples measured were the height, length, width, and weight.

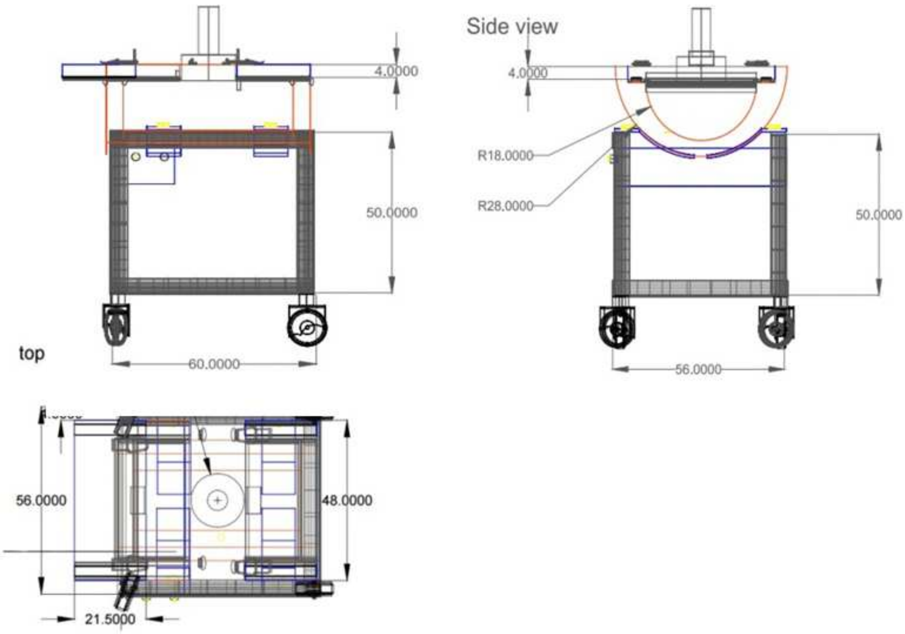

Figure 2: Orthographic Projection of the Low-Pressure Dryer

4. RESULT AND DISCUSSIONS

The preliminary result of the oven-dried fish samples gave an average of the water content of 74 % wb. The machine fabricated and samples of fish A and B dried are shown in Plate 1. The two fish samples used had an average live and dead weight of 0.77 and 0.75 g respectively. The average length, breadth, and width were 45.5, 6.5 and 4.3 cm respectively. During the dryer evaluation, **a** significant level of vacuum of 3.6KPa has attained a readout taken from the vacuum gauge has shown Plate 1. This vacuum head was maintained, with the aid of thermocouple that controls the temperature in the cabinet, throughout the drying period that lasted for 10 hours. The difference in weight was observed every thirty minutes interval throughout the 10 hours of drying with temperature varying from 38 to 43^{o} C. The drying rate of the gutted sample A was higher than that of the ungutted sample B. The energy and power required for this operation was approximately 579KJ and 16w respectively. The average moisture content removed from the samples was 67.5% dry basis. This value of moisture removed compares favorably with values of moisture 80% reported in literature, indicating 84.38% water removal efficiency of the machine.

The effective moisture diffusivity value of $7.58\times10^{-11}m^2/s$ was obtained which approximately is within range of standard effective moisture diffusivity of catfish which is 8×10^{-10} to 8×10^{-11} (Panagiotou, et al2004). An overall drying efficiency of 85% was also obtained.

Figure 3: (a) Aerial View of the Vacuum Dryer, (b) Isometric View of the Dryer, (c) Fresh Cat Fish Samples, (d) Dried Cat Fish Samples

5. CONCLUSIONS

The vacuum drying unit was able to dry the fish samples within 10 hours at a throughput drying of 84.4 % moisture removal efficiency. This method is of great value for fish farmers who would like to preserve their fish harvest and have good market value without the threat of spoilage of fish products which is still at vogue with the present productions at the local level.

REFERENCES

1. *Adebowale B.A., Dongo L.N., Jayeola C.O., Orisajo S.B. (2008) Comparative quality assessment of fish (Clariasgariepnius) smoked with cocoa pod husk and three other different smoking materials. Journal of Food Technology. 6: 5-8.*
2. *Baird-Parker T.C. (2000) The Production of Microbiologically Safe and Stable Foods. The Microbiological Safety and Quality of Food, Aspen Publishers. Gaithersburg. USA. pp: 3-18.*
3. *Cengel,Y.A, and Michael A. Boles 2006.Thermodynamics: An Engineering approach*
4. *Clucas I.J. 1975. Fish spoilage and general introduction to preservation. Food and agricultural organization of the united nations/Swedish international dev. Authority seminal on planning and implementation of utilization of programs in Africa.*
5. *Clucas.I.J. 1982.Fish Handling, Preservation and Processing in the Tropics.Part2 Report of Tropical Institute.*
6. *Koula, D., & Souhila, T. Antibacterial Effect of Arbutus Unedo L. Fruit and its Essential Oils on Salmonella Typhi (ATCC 14028) and Pseudomonas Aeruginosa (ATCC 27853).*
7. *David E. and Whitfield V. (2000), Solar Dryer Systems and the Internet: Important Resources to Improve Food Preparation, Retrieved February 27, 2011, from http://solarcooking.org/drying/Whitfield-drying1.html*
8. *Earle R.L. 1983 Unit operation in food processing*
9. *FAO (2010) Fisheries and aquaculture topics: Food security and fisheries. Topics Fact Sheets.Text by Peter Manning. Fisheries and Aquaculture Department, Rome.*
10. *Fraser O, Sumar S (1998) Compositional changes and spoilage in fish. Nutr. Food Sci. 5: 275-279.*
11. *Das, M. K. (2014). Starter culture development of sindol-a fermented fish product of Assam. International Journal of Agricultural Science and Research, 4(2), 107.*

12. *Holman J.P. (1997), Heat Transfer 8th edition, p. 479, New York: McGraw-Hill, Inc*

13. *Joseph H. Keenan, Frederick G. Keyes, Phillip G. Hill, & Joan G. Moore, (1992), steam tables: Thermodynamic Properties of Water Including Vapor, Liquid, and Solid Phases, Malabar Florida: Krieger Publishing Company*

14. *Suman, A. K., Ojha, M., Saini, V., & Sharma, O. Assessmentof Water Quality and Fish Growth in Micro-Water Sheds of Banswara District in Southern Rajasthan.*

15. *Khurmi R.S. and J.K.Gupta.2005.Machine Design.*